Defense Technical Information Center
Compilation Part Notice

ADP010884

TITLE: Data Communication and Data Fusion in
Rapid Environmental Assessment: State of the Art

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: New Information Processing Techniques for
Military Systems [les Nouvelles techniques de
traitement de l'information pour les systemes
militaires]

To order the complete compilation report, use: ADA391919

The component part is provided here to allow users access to individually authored sections
of proceedings, annals, symposia, ect. However, the component should be considered within
the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP010865 thru ADP010894

Data Communication and Data Fusion in Rapid Environmental Assessment: state of the art

(May 2000)

Alex Trangeled, Frederik H. Vink[1], and Alessandro Berni
NATO SACLANT Undersea Research Centre
Viale S. Bartolomeo, 400
19138 La Spezia, Italy

1. Introduction

In the evolving world of international security, NATO faces new challenges. In early 1990's the Alliance studied the new security situation and revised its strategically concept. Future conflicts will occur in a wider area of interest with lower intensity and on a regional scale; the area of operation is in many aspects unknown. An active effort is necessary to be able to combat future threats.

The mission of the SACLANT Undersea Research Centre (SACLANTCEN), based in La Spezia, Italy, is to conduct research in support of NATO's maritime operational requirements. Considerable efforts are being made to identify and counter the threats related to underwater warfare. SACLANTCEN performs operations research and analysis, research and development in the field of Anti Submarine Warfare (ASW), Mine Counter Measures (MCM) and Military Oceanography (MILOC).

Rapid Environmental Assessment (REA) is one of the five thrust areas of SACLANTCEN's Scientific Programme of Work (SPOW). The goal of the Centre's REA program is to research methods for providing warfighters and planners with tactical relevant information in a tactical relevant timeframe.

This document concentrates on the technological aspects of data processing, fusion and transmission, illustrating the evolution of the techniques adopted and their innovative impact on MILOC activities.

2. Rapid Environmental Assessment: supporting NATO's Crisis Response Doctrine

The concept of Rapid Environmental Assessment (REA) has emerged in recent years as one of the most interesting research topics in MILOC.

REA is defined as:
"The acquisition, compilation and release of tactically relevant environmental information in a tactically relevant time frame".

The definition of *"tactically relevant time frame"* can range from several months, during the operational planning phase, to a few hours, during naval operations.

2.1 Planning

Conventional planning of naval operations commenced months prior to the execution. When the time of execution comes near, the mission is planned in detail and at that point a near real time information flow becomes more important.

In the past, MILOC efforts have been concentrated at gathering information from a strategically important static area. Data was collected over a long period, and several months would pass before actual reporting of the results occurred. When the need emerged, it would eventually find its way into a Tactical Decision Aid (TDA) such as NATO's Allied Environmental Support System (AESS), to produce Environmental Briefing Dockets (EBD). Unfortunately, this process would typically take two to three months, so that the end product would be neither timely or current [1].

---

[1] Seconded from the Royal Netherlands Naval College (RNLNC)

In consideration of the new NATO security scenario that has to cope with multiple risks, including crisis management and humanitarian operations in littoral areas, there is a high probability that the designated operation theatre is an area for which the availability of *a priori* knowledge is minimal. Environmental information should however be available within a crisis response time scale of a few weeks, in order to gain some tactical advantage.

"The tactical advantage will probably depend not on who has the most expensive, sophisticated platforms but rather on who can most fully exploit the natural advantages gained by thorough understanding of the physical environment."

Rear Adm. W. G. "Jerry" Ellis, U.S. Navy, Oceanographer of the Navy, 1999

What is considered to be essential in the planning phase is a prediction capability to provide the planner with a stop light decision aid: green, yellow and red to assign the possibility of executing a mission. Predictive capabilities are useful to foresee a change in the environment that may influence the tactical deployment of people, material or systems.

Prior to and during the executional phase of an operation, knowledge of the environment should be valid and up to date. This knowledge should express tactical useful information; the newly obtained environmental information should be made available for assimilation.

The principal aim of SACLANTCEN's REA investigates efforts is to provide a framework for the prediction of sonar parameters and to supply ASW, MCM and Amphibious Warfare (AW) commanders with environmental information within a time scale compatible with tactical operations. Methodologies and techniques that enable the collection, processing and distribution of environmental data and products within a compressed time frame are implemented, integrating traditional methods of information gathering in MILOC with modern communications and data processing techniques.

3. Data fusion

Environmental information is made available to the warfighter using dependable information technology assets for information gathering, transmission and presentation: state of the art Commercial-Off-The-Shelf (COTS) solutions constitute the basis for REA research and development efforts.

The data collected during an REA survey are transferred to a central location, termed the Data Fusion Center (DFC), from where it can be easily retrieved by the customers. Standard Internet protocols are used for data exchange, for maximum interoperability and platform-independence. Data uploads to the DFC are done by File Transfer Protocol (FTP), data presentation and retrieval is handled by a standard Hyper Text Transfer Protocol (HTTP) server, allowing customers to browse the archive using a World Wide Web (WWW) -browser.

Type-, time- and space-domain search engines have been implemented, presenting the customer with a list of data sets pertaining to his specific area of interest.

Up to now, the main emphasis has been on delivering unclassified data over the Internet, using IP address and password authentication for access control. The unclassified contents have been subsequently transferred to the NATO Initial Data Transfer System (NIDTS), where classified products have been added to the server contents.

4. Communications in support of at-sea experiments

SACLANTCEN started exploiting Internet technologies in support of field experiments since 1994, with real-life concept tests during surveys Yellow Shark 95 and Winter Sun 95 [2]. The following *Rapid Response* (RR) operations involved the evaluation of a wide range of COTS communication methodologies to satisfy the REA requirements. The resulting infrastructure was used to transfer data (both raw and processed) from at-sea platforms to ashore centres and vice versa.

Present research is aimed at the definition of turnkey solutions that can be deployed on site with small advance notice. A *REA in A Box* (RIAB) prototype has been prepared and demonstrated during NATO exercise *Linked Seas 2000*. Furthermore, the goal of future warfighter consultation is to define and prioritize the products that really are considered helpful during the planning and execution of a naval operation, in order to define the necessary REA data flow.

5. Rapid Response REA operations

The *Rapid Response* series of operations, conducted between 1996 and 1998, demonstrated how COTS Internet technologies could be successfully integrated to build *ad-hoc* networks in support of REA surveys. *Rapid Response* and the other experiments conducted so far constitute proof of the effectiveness of the REA concept.

5.1 REA Data and products

During *Rapid Response*, a variety of data types were distributed to survey participants and customers, ranging from simple American Standard Code for Information Interchange (ASCII) files containing Expendable Bathythermograph (XBT) data to large image files containing high resolution satellite remote sensing data.

In consideration of the high volume of data that was generated by survey data contributors, standardization in file formats was found to be essential, to ensure the data consistency and prompt data fusion. File format standardization was not limited to naming issues, but was extended to the data set structure and to the attachment to the file of geographic/time information, in order to ease subsequent retrieval. The header files were subject to minor changes between *Rapid Response 96* and *Rapid Response 98*.
The following sections, extracted from [3], provide a comprehensive listing of supported data types.

5.1.1 Atmosphere
- Meteorological ship observations
- Upper air observations by weather balloons
- Drifting meteorology buoys, deployed from aircraft

5.1.2 Beach and hinterland
- Landsat satellite images
- Systeme Pour l'Observation de la Terre (France) (SPOT) satellite images
- Aerial photographs
- Photogrammetry
- Beach photographs
- Trafficability measures by hand-held bottom penetrometer
- Trafficability assessed by conventional methods
- Maps
- Reports
- Beach profiles
- Surf measurements
- Numerical surf predictions

5.1.3 Ocean surface
- Tidal water level
- Sea surface height from satellite altimeter
- Wave height from satellite altimeter
- Wave height and spectrum from wave rider buoys
- Ocean features by radar images from satellites
- Surface roughness and microwave emission indicating surface wind
- Radiation temperature images of the sea surface
- Ocean color
- Lagrangian current measurements by surface drifters

5.1.4 Water column
- Deep currents by drifters dragged to several hundred meters depth
- Eulerian current measurements by moored current meters
- Current profiles by acoustic current profilers (ADCP) on the ocean bottom
- Current profiles underway by ship borne ADCPs
- Temperature profiles by ship deployed expendable probes (XBT)
- Temperature profiles by air dropped probes (AXBT)
- Temperature, salinity and derived parameters by Conductivity Temperature Depth (CTD) probes
- High resolution parameter fields by towed CTD chains
- Water samples for laboratory analysis

- Transparency by Secchi discs
- Transparency from multi-color satellite imagery
- Chlorophyll from multi-color satellite imagery
- Shipping density (for noise assessment) by naval patrol aircraft
- Spectral ambient noise by sonobuoys
- Directional noise by towed hydrophone arrays
- Reverberation levels by towed hydrophone arrays
- Transmission loss

5.1.5 Ocean bottom

- SPOT satellite images for depth and bottom type in shallow waters
- Airborne laser system for depth in shallow waters
- Single beam echo sounding
- Multibeam area mapping
- Side scan sonar imaging
- Assessment by video cameras
- Bottom grabs
- Cores
- Mechanical bottom parameters by Expendable Bottom Penetrometers (XBP)
- Seismic reflection profiles
- Sound velocity in the bottom layers
- High frequency bottom reverberation
- Inverse modeling of bottom parameters

5.2 Rapid Response 96

Operation *Rapid Response 96* (RR96) took place in a portion of sea between Sicily, Tunisia and Sardinia. It was the first time the experimental concept of REA was validated in an operational context. It was held in support of the Commander in Chief South Atlantic (CINCSOUTHLANT) annual maritime LIVEX, Dynamic Mix 96 in addition to the associated MCM exercise Damsel Fair.
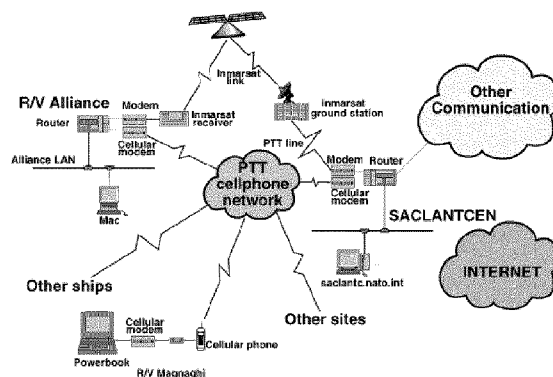

Figure 1: Network Architecture for Rapid Response 96-98 [4]

A total of 6 vessels took part in the REA survey. SACLANTCEN participated with NATO Research Vessel (NRV) Alliance and NRV Manning; other participants were USNS Pathfinder, HMS Herald, FS La Gazelle and the Italian research vessel Magnaghi. The survey vessels transmitted the collected data by standard FTP to the SACLANTCEN Data Fusion Center using Italian ETACS or GSM cellular telephone networks.

The cellular phones were encapsulated in a watertight box and mounted directly on the mast, in order to minimize cable loss. For the ETACS phones, ranges of up to 100 Km from shore were obtained. GSM range was limited to approx. 32 Km.
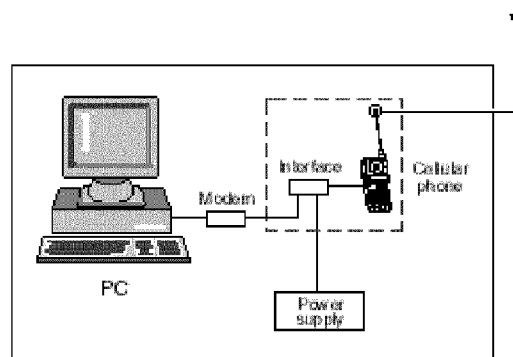

Figure 2: Cellular phone installation RR 96-98 [4]

Maritime reconnaissance for ambient noise evaluation and AXBT measurements were conducted from aircraft based at NAS Sigonella in Sicily. From here, the data were transmitted to the DFC at SACLANTCEN via dial-in through the NATO telephone network. A WWW server at SACLANTCEN was used to present data in an organized structure to external customers.

A copy of all data was transferred using Satellite Communication (SATCOM) to USS La Salle for use during Dynamic Mix 96.

5.3 Rapid Response 97

Rapid Response 97 (RR97), the second exercise of the series, was conducted to support Dynamic Mix 97 and Damsel Fair, taking place in a large area, including the Strait of Messina, the Ionian, Adriatic and Aegean Seas.

NRV Alliance was the leading ship of a fleet of 8 survey vessels. The other vessels were FS D'Entrecasteaux, WFS Planet, HNLMS Tydeman, HMS Roebuck, USNS Pathfinder, HENA Pytheas and ITS Crotone.

Where the data fusion took place exclusively at SACLANTCEN in 96, during RR97 the task was undertaken at sea by NRV Alliance, where most data processing was performed. A two-way mirroring process of both raw and processed data was implemented to/from the SACLANTCEN Data Fusion Center via Inmarsat B, with updates at least every 12 hours.

A detailed database was maintained at both ends to ensure that all parties had a fully up to date data set. The other survey ships had access to the Data Fusion Center via ETACS dial-up connections and Inmarsat, enabling them to exchange data with the server mirror at SACLANTCEN.
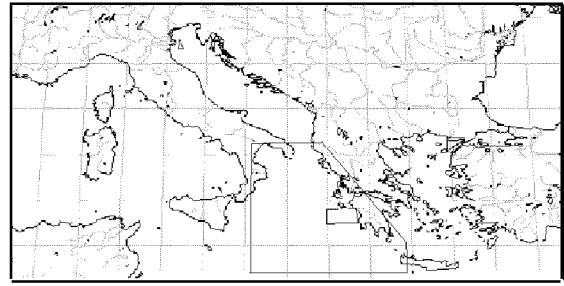

Figure 3: Operational areas for Rapid Response 97 [4]

5.4 Rapid Response 98

Rapid Response 98 (RR98) took place in the Atlantic area south of the Iberian Peninsula. This third and final exercise of the series focused on coordinated environmental reconnaissance in support of Strong Resolve 98. The REA activities integrated air, sea and satellite remote sensing operations with archive data searches to acquire essential oceanographic and atmospheric data for Mine Warfare (MW), AW and ASW.

Participants to the exercise included NRV Alliance, HMS Roebuck, USNS Pathfinder, WFS Planet, SPS Tofino and FS D'Entrecasteaux.
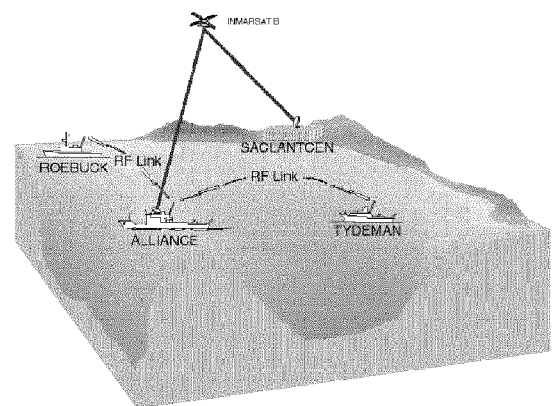

Figure 4: Summary of Network Architecture for RR98 [4]

As in the previous year, NRV Alliance hosted the Data Fusion Centre for the survey. The other survey vessels could interact with NRV Alliance by radio links using standard Internet protocols, or access the mirror at SACLANTCEN via GSM dial-in. At the end of REA phase, the data fusion operations control was transferred to

SACLANTCEN, until the completion of Strong Resolve. A mirror of the REA unclassified web was made available to NATO users also via NIDTS.

6. Current efforts

The *Rapid Response* series of demonstrated how COTS network technologies could be successfully integrated to build *ad-hoc* networks in support of REA surveys. *Rapid Response* and the other experiments conducted so far constitute proof of the effectiveness of the REA concept.

This initial data communications infrastructure relied heavily on cellular phones. However, cell phones are not an option in a denied area. In addition to that, the RF link used for ship-to-ship communications in RR98 did not provide sufficient bandwidth for effective transmission of high-resolution data.

The complexity in configuration and operation of both data processing and communication systems was originally mitigated focusing on the human factor, that is, relying at all times on experienced technical and scientific personnel. Clearly this can not be the case in an operational scenario. The availability of reliable and scalable ship-to-ship links and data fusion architectures is of paramount importance to the effectiveness of REA surveys: present efforts are therefore concentrated on defining a general architecture suitable for use in operational conditions.

6.1 RIAB: REA in A Box

In the present context, where interoperable SATCOM is not readily available on all vessels, environmental measurements are relayed via spread-spectrum line-of-sight wireless data links to a data fusion centre afloat (e.g. a command ship), which can be positioned several miles away. Data are then transferred to a fusion centre ashore using a SATCOM gateway, where they are made available to the REA community (data providers, product developers, and customers) using wide-area computer networks (WAN).

The formalization of the above concept is leading to the definition of a *REA-in-a-box* (RIAB) system: RIAB is a fully-featured solution that can be deployed on site with little advance notice, to provide a low-cost, easy to use system for data exchange between survey participants.

The RIAB system is made of two entities, client and servers, that interoperate to provide an end-to-end solution to the REA requirements.

6.1.1 RIAB Client

The RIAB client system is a package integrating a Personal Computer (PC) and a Spread Spectrum (SS) wireless router for ship-to-ship communications, to be installed on every vessel participating to the REA survey.
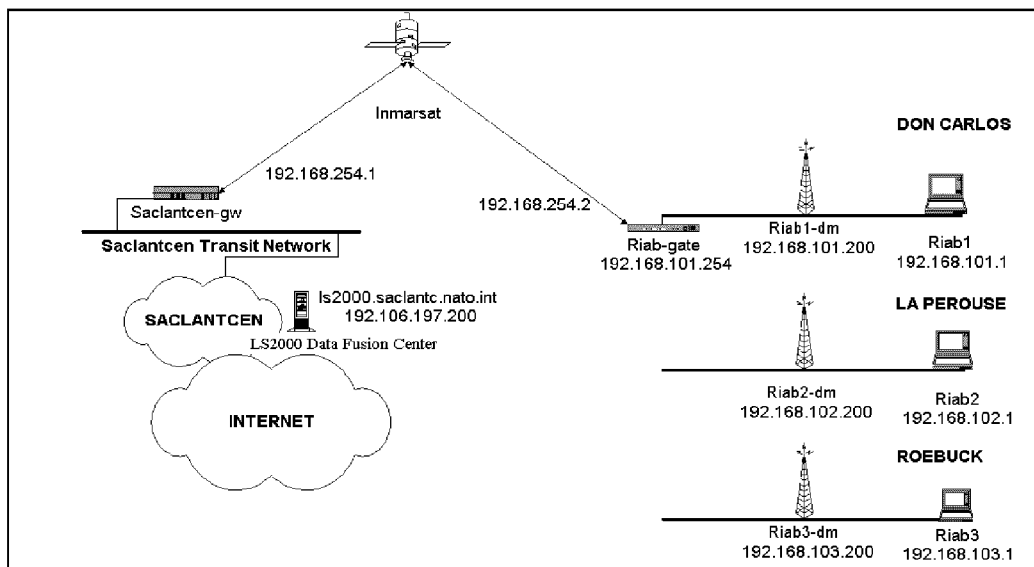

Figure 5: RIAB System for Linked Seas 2000 - Wireless Network

6.1.2 RIAB Server

The RIAB server system is packaged as the client, but is supplemented by an Inmarsat-B High-Speed Data (HSD) satellite link. The transition to military SATCOM systems is a fairly straightforward process.

6.1.3 RIAB Data flow

The RIAB software implementation is focused on robustness and user-friendliness. An elaborate mirroring scheme handles the actual relaying of data, so that all survey vessels maintain copies of all data by recursive data pull. This means that any RIAB system is capable of delivering not only its own data, but also data from any other client, with which a successful data exchange (synchronization) has been effected.
All data received by the RIAB server by the different clients will be subsequently packaged, compressed and transmitted to the remote Data Fusion Center.

6.1.4 Linked Seas 2000

The first field test of a RIAB prototype was effected in April-May 2000, during the REA precursor phase to the NATO *Linked Seas 2000* exercise. The present implementation has been implemented on COTS portable computers using the Linux operating system.

Three survey vessel were equipped with RIAB equipment: NRP Don Carlos (PT), FS Laperouse (FR), and HMS Roebuck (UK), with Don Carlos acting as the RIAB server.
Practical communication ranges between ships were in the order of 12 nautical miles. Overall excellent results were obtained, since all data from all survey vessels (in the order of 30 MB) was delivered with a maximum delay of 24 hours time. Customer feedback was quite positive; the RIAB end-users were able to operate the equipment successfully after a 20-minute brief. Data exchange could be monitored continuously through a normal web-browser.

The few problems that were encountered during LS2000 were diagnosed and corrected remotely during a routine data transfer, without specialist personnel onboard the vessels involved.

7. RIAB - the concept evolving

Since REA support systems such as RIAB are evolving towards implementation suitable for operational use, a continuous interaction with the warfighters, the people who actually have to utilize this information, is necessary.

Raw data are fairly immediately available and can be presented nicely on screen; the products are presented to the warfighter after post-processing and assimilation of the available information. Efforts from multiple and complementary expertise such as oceanographers, meteorologists, operations research, communications and information technology experts and last but not least the customer at sea, the warfighter, need to be fused to clearly define the REA tactical product list. To facilitate this, a two-way information flow is required between the DFC and the naval units.

Future developments provide for this two-way capability. They involve the coupling of RIAB type systems to classified military networks and provide access from the participating units to the full contents of the Data Fusion Center. The fusion center could be located anywhere, including the Command Unit responsible for the survey area, as long as it has the necessary satellite uplink capability, be it permanent or on-demand (from both peers). Such an infrastructure provides for near real-time scientific support and remote counseling from experts in various fields. Naval units are able to receive the most up-to-date environmental products and Tactical Decision Aids through this two-way network.

8. Conclusions

The scientific community and the warfighter should address points of importance in the naval REA product, to fully exploit its value of tactical oceanography to provide battle space awareness for the warfighter at sea.

A general culture aspect should also be addressed. Warfighters and operators of sonar systems have done their job for many years to the best of their ability: now the availability of REA methodologies can radically change the way in which they work. To fully exploit the power of REA, navies need to become acquainted with the new concept. Future development efforts mandate

an involvement of a warfighter perspective to validate progress and prompt operational needs.

RIAB, in its first implementation, has vastly improved REA data management and distribution. Further efforts are required however to arrive at a turnkey MILSPEC system.

Currently endeavors are undertaken to verify the military impact of REA in depth. A dialog between the scientific community and the warfighter is established and will remain important for further REA product development.

9. References

[1] Hammond, N. Rapid Response 96, A demonstration of NATO's Rapid Environmental Assessment capability. *In*: Poulinquen, E., Kirwan, A.D. *and* Pearson, R.T., *editors*. Rapid Environmental Assessment, SACLANTCEN Conference Proceedings Series CP-44, NATO UNCLASSIFIED. La Spezia, Italy, NATO SACLANT Undersea Research Centre, 1997: pp 21-23 [ISBN 88-900194-0-9]

[2] Bovio, E., Max, M.D., Spina, F. *and* Berni, A., Communication Technology in support of SACLANTCEN Programme of Work. *In*: Poulinquen, E., Kirwan, A.D. *and* Pearson, R.T., *editors*. Rapid Environmental Assessment, SACLANTCEN Conference Proceedings Series CP-44, NATO UNCLASSIFIED. La Spezia, Italy, NATO SACLANT Undersea Research Centre, 1997: pp 21-23 [ISBN 88-900194-0-9]

[3] Sellschopp, J. Experience gained and lessons learnt in three years of Rapid Response, *In:* Undersea Defence Technology Europe 98, London, UK, Nexus Media Ltd.: pp 69-73 [ISBN 1899919 28 7]

[4] Trangeled, A., Franchi, P., Berni, A., Data Communication and Data Fusion Architectures for Rapid Response 96-98, SACLANTCEN SR-296. La Spezia, Italy, NATO SACLANT Undersea Research Centre, 1999.